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UNITED STATES DEPARTMENT OF AGRICULTURE

In cooperation with the
Pennsylvania Agricultural Experiment Station and the Pennsylvania Department of Agriculture

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INVESTIGATIONS OF POTATO WART.[1]

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I.—THE VARIETAL AND SPECIES HOSTS OF SYNCHYTRIUM ENDOBIOTICUM.

By FREEMAN WEISS and C. R. ORTON.

TESTS WITH POTATO VARIETIES AND SEEDLINGS.

When the disease of the Irish potato known as wart was discovered in the United States in 1918 [2] the question of the reaction of American potato varieties to the newly introduced parasite assumed a position of first importance. The fact that certain potato varieties remained entirely free from infection even when grown in soils thoroughly infested by the pathogen, as shown by the behavior of other varieties, had been known in Europe for a number of years, and the cultivation of such resistant varieties was even then regarded as the only means of avoiding the severe crop losses occasioned by this disease. Variety tests conducted in England had included several American sorts, and these were reported upon in 1919 [3] but aside from this, no information was available as to the reaction of American varieties to this disease. However, the severity of infection on the heterogeneous stocks commonly grown in the wart-

[1] This report is based upon cooperative investigations carried on by the Bureau of Plant Industry and the Federal Horticultural Board of the United States Department of Agriculture, the Pennsylvania Agricultural Experiment Station, and the Pennsylvania Department of Agriculture.

[2] Sanders, James G. The discovery of European potato wart disease in Pennsylvania. *In* Jour. Econ. Ent., v. 12, p. 85-90, pl. 3. 1919.

[3] Snell, John. Ormskirk potato trials. Annual report, 1918. *In* Jour. Bd. Agr. [Gt. Brit.], Sup. 18, p. 68-102, fig. 20-33 on 8 pl. 1919.

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infested area showed that susceptible potatoes predominated. Subsequent tests of a large number of tuber selections among the diverse types grown in this area confirmed the fact of the general culture of susceptible types. The bearing of this upon the restricted distribution of potato wart in the United States, as brought to light by the disease survey (Fig. 1), is of particular importance, for it is believed that shipments of potatoes equally capable of introducing the parasite as those which found their way into the mining towns of Pennsylvania may have reached diverse sections of the country, but failed to introduce the disease because of the prevalent culture of immune varieties in many sections.

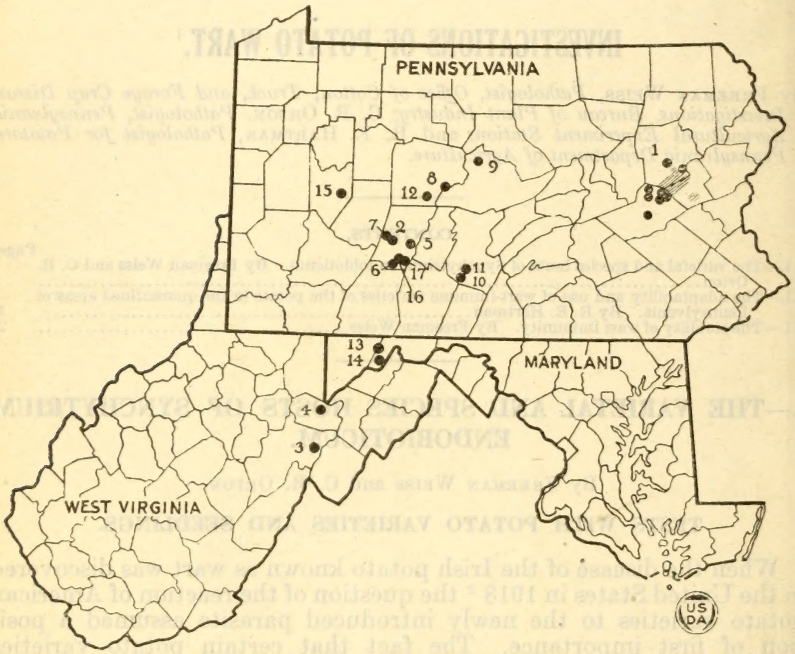

FIG. 1.—Outline map of Maryland, Pennsylvania, and West Virginia, showing the geographical distribution of potato wart on September 1, 1922. Localities of findings: 1, Original eastern Pennsylvania area; 2, Nanty Glo; 3, Whitmer; 4, Thomas; 5, Lilly; 6, Llanfair; 7, Vintondale; 8, Osceola Mills; 9, Clarence; 10, Woodvale; 11, Robertsdale; 12, Smithmill; 13, Mount Savage, Eckhart Mines, and Lord; 14, Midland; Charles Town, and Detmold; 15, Yatesboro; 16, Beaverdale; 17, Onnalinda. (Prepared by the Office of Plant-Disease Survey, Bureau of Plant Industry.)

It became necessary, therefore, to prohibit at once the cultivation of potatoes in all gardens which were known to be infested, but it was thought desirable to permit the continued use of susceptible varieties in the general area, in order to determine the ultimate extent of infestation; meantime, the rest of the country was protected against extension of the disease by a quarantine on the movement of potatoes and materials capable of transporting the parasite from the infested area as then known.

The lateness of the season when wart was discovered prevented making tests of varietal susceptibility in 1918, but during the winter it was determined that the Triumph variety was susceptible. The

following season a systematic test of all obtainable American varieties was begun. In addition, investigations of a number of immune English varieties were made to determine their commercial value as well as their reaction to wart in the United States. A preliminary report [4] of these investigations was issued in 1920, covering the results of the trials of the first season. These tests established the fact that the wart pathogen was consistent in its behavior in America and Europe in that the immune varieties of Europe remained free from infection also in this country. It was furthermore shown that although most American varieties were susceptible, including some of the particularly valuable commercial types, 10 varieties, including the well-known Irish Cobbler, Green Mountain, and Spaulding Rose, could with reasonable assurance be classed as immune.

As a result of these tests it became possible to modify the quarantine regulations in the Pennsylvania areas so as to permit the culture of the immune sorts, Edzell Blue and Spaulding Rose, in infested gardens, and the supplying of approved immune seed potatoes became a function of the quarantine administration. The general effect on potato culture of changing over from the mixed stocks of predominantly susceptible potatoes to selected seed of immune varieties is described in a later section of this bulletin. A similar modification of quarantine procedure has been found advisable in the infested areas in West Virginia and Maryland, and it is now well established that potato culture need nowhere be abandoned on account of this disease so long as suitable immune varieties are available.

The project of determining the wart reaction of all American potatoes and also their adaptability for commercial culture in the regions infested by wart and areas adjacent thereto has been continued on a more extensive scale for three additional years. In general, methods of planting and culture similar to those described in the earlier report have been followed. The site of most of the trial plats has been the vicinity of Freeland, Pa., where gardens which are heavily infested naturally and are in favorable tilth for potato culture are already at hand. Since the same gardens, for the most part, have been employed again and again, accurate information as to the thoroughness and density of infestation is now available, a factor of great importance in analyzing the results. Additional tests have been carried on at Thomas, W. Va., and in the greenhouses of the United States Department of Agriculture at Washington, D. C.

Single rows of a given variety or seedling, crossing the garden transversely and averaging 30 feet in length, have been the standard form of plat, but larger test plantings have been made in some cases. Ordinarily, only a single plat of each variety has been grown each year; that is, no attempt has been made to duplicate plats systematically, but in a number of cases certain varieties have been repeated in other gardens either in the same or a different region. At regular intervals of nine rows a susceptible variety has been planted as an indicator of the presence of the pathogen in a virulent state. As check varieties, Triumph and various stocks of Rural New Yorker and Up-to-Date have been employed; the last two named are very readily susceptible and react to infection by the

[4] Lyman, G. R., Kunkel, L. O., and Orton, C. R. Potato wart. U. S. Dept. Agr., Dept. Circ. 111, 19 p., 4 fig. 1920.

production of very striking overgrowths, so that check rows commonly exhibit practically 100 per cent infection.

Any variety with 20 per cent or more of tuber infection was classed as susceptible and forthwith discarded, but stocks which were infested to a lesser degree were grown another year before discarding. Where no infection occurred, the entire stock was saved for successive planting year by year until immunity was considered definitely established. Where a single hill or only two or three tubers showed wart formation, as occurred in but very few instances, the infected hill was discarded and the test repeated with the remainder of the stock.

It is to be noted that, owing to the limited occurrence of areas infested by wart our tests have not been carried on with the same degree of attention to large size and systematic duplication of plats, repeated through several years or in a number of localities, that has been characteristic of similar tests in England and Germany.[5] Nevertheless, it is felt that a very high degree of reliability attaches to the results here reported. This question was discussed briefly in the preliminary report[6] to which reference has been made. The following considerations derived from more extensive experience may be cited in addition:

Purity of stocks.—The material which has been available for these tests has been of exceptional quality as regards uniformity and trueness to type. For the most part these stocks have been grown by the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry for a number of years at the potato-breeding farm of the United States Department of Agriculture in Aroostook County, Me., and mixtures have been entirely or practically eliminated. This has avoided at the outset most of the difficulty due to errors in variety names and to mixed types nearly always inherent in lots obtained from commercial seedsmen. Likewise, the seedlings upon which these tests have been made do not have the heterogeneous and uncertain element that prevails in material obtained from amateur plant breeders, but are selected lines derived from the controlled crossing of known parents.

Consistent results from trials.—All varieties for which a definite report of immunity is here made have been carried through two or more years, surviving tests conducted in at least three gardens, for the most part located in different regions. A few others indicated as probably immune by the tests of the past season are entered in the tables as immune, but with a question mark.

These variety tests were begun in 1919 under a cooperative agreement between the Bureau of Plant Industry and the Federal Horticultural Board of the United States Department of Agriculture and the Pennsylvania Agricultural Experiment Station. The same arrangement was continued in 1920 and 1921. A similar test was carried out in cooperation with the Agricultural Experiment Station of West Virginia. In 1920, feeling the need for further information as to the adaptability of some of the immune varieties as compared with that of the standard susceptible varieties grown in the wart-infested areas, the Pennsylvania State Department of Agriculture began tests of local varieties collected in the quarantined areas as compared with a number of immune stocks, the introduction of which it was thought would be desirable for purposes of regulated planting. These trials led to the collection of considerable data on the relative value of immune and susceptible varieties in districts situated climatically like those infested with the disease and furnished

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Appel, O. Über die Anfälligkeit und Widerstandsfähigkeit verschiedener Kartoffelsorten gegen Krebs. Arb. Gesell. Förd. Baues and Verwend. Kartoffeln, Heft 15, 19 p., fold diagr. 1918.

Lyman, G. R., and others. Op. cit.

also a demonstration of the practicability of changing over to new varieties in localities threatened by the introduction of the wart parasite. This cooperative report is issued to bring together all available information regarding the reaction to wart and the suitability of American potato varieties for purposes of potato-wart quarantine. Furthermore, in order to present the studies upon additional host range which were carried on by the United States Department of Agriculture, in their proper relation to the varietal investigations with potatoes, a summary of all planting tests with miscellaneous solanaceous species in wart-infested soil has been appended. The susceptibility of tomato varieties to wart was discovered in 1919 [7] and extensively confirmed in 1920. The need for further information as to the importance of this host from the standpoint of quarantine administration led to the adoption in 1921 of a cooperative agreement between the Federal Horticultural Board and the Pennsylvania State Department of Agriculture for testing on a large scale all obtainable tomato varieties.

As already stated, most of the named varieties of potatoes and all the seedlings employed in these tests were furnished by the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry. One collection was received from the Agricultural Experiment Station of Prince Edward Island, and a number of local varieties have been obtained from growers. In the first year of the tests 29 immune varieties were received from England through the courtesy of Sir Lawrence Weaver, of the Board of Agriculture and Fisheries. Duplicates of some of these, together with a number of additional stocks, were imported in 1920 by J. G. Sanders, of the Pennsylvania State Department of Agriculture. By an arrangement between the Federal Horticultural Board and William Stuart, of the Office of Horticultural and Pomological Investigations, new varieties received by that office from abroad are grown for one year in quarantine before being tested in Maine or elsewhere. This arrangement has resulted in including several varieties received from Scotland and Holland in the wart-reaction trials at Freeland, Pa. Finally, a collection of German varieties was received from E. Schaffnit, of Poppelsdorf, Bonn, in 1921 and carried through two years, and a collection of eight French varieties, furnished by E. Foëx, of the Station de Pathologie Végétale, France, was available for testing in 1922. The results of the trials covering four years are assembled and summarized in Table 1.

The American varieties are placed in groups according to Stuart's classification.[8] It should be noted, however, that in material of so diverse a germinal complexion as the potato the varietal similarities which constitute the basis of a horticultural classification can not afford an index to genetic relationships adequate in all cases to predict in advance of actual testing the wart reaction of a variety from the known behavior of horticulturally similar types. This is well illustrated by the behavior of the varieties of the Early Michigan and the Green Mountain groups. In the former group, Early Harvest, Ehnola, Extra Early Sunlight, and White Albino are regarded as immune, while Early Sunrise and Early White Albino are susceptible (Pl. I). Among the varieties belonging to section 2 of the Green Mountain group, which have faintly colored sprouts, Charles

[7] Lyman, G. R., and others. Op. cit.
[8] Stuart, William. Group classification and varietal descriptions of some American potatoes. U. S. Dept. Agr. Bul. 176, 59 p., 19 pl. 1915.

Downing (Ormskirk, England, trials, 1919), and Idaho Rural, are immune, whereas American Giant and Empire State are readily susceptible. In the white-sprout section Carman No. 1, Clyde, Gold Coin, Delaware, Dreer Standard, Green Mountain Junior, Norcross, Snow, State of Maine, Uncle Sam, and Wee MacGregor are regarded by many commercial growers as identical,[9] yet strains grown under these names in the tests here described have reacted diversely to this disease (Table 1). Similar diversity of reaction is exhibited in the Burbank and Early Rose groups. Only extensive testing of numerous stocks of a given variety obtained from different sources and a careful checking of varietal characters to detect differences can eliminate such confusion. On the other hand, the Early Ohio, Rural New Yorker, and Triumph groups comprise only susceptible varieties, while the Cobbler and Peachblow groups are composed entirely of immunes.

TABLE 1.—*Reaction of American and European potato varieties to potato wart.*

[EXPLANATION.—Column 1: The test data for varieties marked with a star (*) were furnished by R. E. Hartman. Column 2: The data given were furnished by William Stuart. The Field Laboratory of Plant Pathology, Charlottetown, Prince Edward Island, is abbreviated to Field Laboratory, Prince Edward Island. Column 4: >=Numerous. Column 5: The following symbols are used to indicate varying degrees of susceptibility or resistance: 0=immune (every plant free from infection in repeated trials); ±=slightly susceptible (less than 20 per cent of individual plants in any test infected, weak development of warts); +=moderately susceptible (usually less than 50 per cent of plants infected, weak to strong development of warts, depending upon which part of the plant is attacked and the stage of growth at infection); ++=very susceptible (all or most of the plants in a test infected, copious development of overgrowths on all susceptible parts, Pls. I to IV). The question mark (?) implies not that the conclusion is doubtful in this instance, but that it has not been confirmed by repeated tests.]

Group and variety.	Source of seed.	Years tested.	Tests made.	Wart reaction.
1	2	3	4	5
GROUP I.—Cobbler:				
Cordon's Early Snowflake	Cordon Bros., Rockford, Ill	2	2	0
Early Eureka	W. H. Maule, Philadelphia, Pa	2	2	0
Early Petoskey	Darling & Beaham, Petoskey, Mich	3	3	0
First Early	S. M. Isbel & Co., Jackson, Mich	2	2	0
Irish Cobbler	H. E. Gero, Rutland, Vt	3	3	0
Do	I. B. Bradford, Goldenridge, Me	3	3	0
Do	Wilfrid Boulter, Prince Edward Island	1	1	0
Do	J. Bolgiano, Baltimore, Md	1	1	0
New Early Standard	Henry A. Dreer (Inc.), Philadelphia, Pa.	3	3	0
GROUP II.—Triumph:				
Bliss Triumph	F. S. Campbell & Sons, Three Lakes, Wis., and others.	3	>	+
Early Prospect	Smith Bros., Auburn, N. Y	1	1	+
White Bliss Triumph	T. W. Wood & Sons, Richmond, Va	1	1	+
GROUP III.—Early Michigan:				
Brown Beauty (known locally in Colorado as Barkley's Prolific).	C. F. Clark, Greeley, Colo	1	1	++
Early Harvest	C. D. Woods, Orono, Me	2	2	0
Early Sunrise	Robert Buist Co., Philadelphia, Pa	1	1	++
Early White Albino [1]	Johnson Seed Co., Leominster, Mass	1	1	+
Ehnola	E. F. Corey, Presque Isle, Me	4	4	0
Extra Early Sunlight	T. W. Wood & Sons, Richmond, Va	3	3	0
White Albino	Johnson Seed Potato Co., Richmond, Me.	2	2	0
GROUP IV.—Rose:				
Early Rose	Several sources	3	3	+
Evergreen [2]	E. V. Hardenburg, Ithaca, N. Y	1	1	+
Northern King	Iowa Seed Co., Des Moines, Iowa	2	2	0
Seneca Beauty (greenhouse test).	Gurney Seed & Nursery Co., Yankton, S. Dak.	1	1	+
Spaudling Rose	Several sources	4	>	0
White Rose [3]	Wesco Seed Co., Rochester, N. Y	3	3	0
Woodbury's White Rose	Vaughan's Seed Store, New York City.	1	1	+

[1] A variety received under this name from Beckert's Seed Store, Pittsburgh, Pa., in 1922 proved to be Irish Cobbler and was immune.
[2] Doubtfully referable to Rose group on account of its very late growing habit.
[3] The stock grown under this name is not White Rose, but probably Burbank.

[9] [Ontario. Potato Council.] [Potato varieties decided to be identical.] *In* Potato Mag., v. 1, no. 7, p. 15. 1918.

TABLE 1.—*Reaction of American and European potato varieties to potato wart*—Contd.

Group and variety.	Source of seed.	Years tested.	Tests made.	Wart reaction.
1	2	3	4	5
GROUP V.—Early Ohio:				
Early Ohio	C. F. Clark, Greeley, Colo.	2	2	+
Do	Joseph Harris, Coldwater, N. Y.	1	1	+
Late Ohio	C. F. Clark, Greeley, Colo	1	1	+
White Ohio	do	1	1	++
GROUP VI.—Hebron:				
Aroostook Pride [4]	Selden McGlauflin, Presque Isle, Me.	1	1	+
Beauty of Hebron		1	1	+
Country Gentleman [5]	Beckert's Seed Store, Pittsburgh, Pa.	2	2	+
Early Beauty of Hebron	Robert Buist Co., Philadelphia, Pa.	2	2	+
Early Bovee	Beckert's Seed Store, Pittsburgh, Pa.	1	1	±
New Green *	Pennsylvania Department of Agriculture.	1	1	++
GROUP VII.—Burbank:				
Burbank	L. A. Hawkins, Middle River, Calif.	2	2	0
California Russet	Low S. Darling, Petoskey, Mich.	1	1	+
Imperial Burbank *	Pennsylvania Department of Agriculture.	1	1	?0
Netted Gem	William Wagner, Jerome, Idaho	1	1	+
Russet Burbank	Colorado Seed Co., Denver, Colo.	1	1	0
White Burbank [6]	California Seed Co., San Francisco, Calif.	1	1	±
GROUP VIII.—Green Mountain:				
American Giant [7]	J. Bolgiano, Baltimore, Md.	1	1	+
American Giant [8]	H. F. Michel, Philadelphia, Pa.	2	2	0
Bountiful	Cordon Bros. Seed Co., Rockford, Ill.	1	1	?0
Carman No. 1	August Mongrain, St. Luce, Province of Quebec.	1	1	+
Delaware	Central Maine Potato Co.	2	3	0
Empire State	Field Laboratory, Prince Edward Island.	2	2	++
Gold Coin	I. D. Adams, South Royalton, Vt.	2	3	0
Green Mountain	Several sources	4	>	0
Green Mountain Junior	Johnson Seed Potato Co., Richmond, Me.	3	3	0
Green Mountain (Gero strain)		2	2	±
Gurney's White Harvest	Gurney Seed & Nursery Co., Yankton, S. Dak.	1	1	+
Idaho Rural *	Pennsylvania Department of Agriculture.	2	2	0
McGregor	Inland Seed Co., Spokane, Wash.	2	2	0
McKinley	W. W. Barnard Co., Chicago, Ill.	3	3	0
New Itaska	Farmers' Seed & Nursery Co., Faribault, Minn.	1	1	+
Norcross	C. O. Hoose, Duane, N. Y., and others.	3	>	0
State of Maine	Jean Carton Gray, Van Buren, Me.	1	2	+
Do	Robert Buist, Philadelphia, Pa.	1	1	0
Do *	Pennsylvania Department of Agriculture.	1	1	0
Vermont Gold Coin	Beckert's Seed Store, Pittsburgh, Pa.	1	1	0
GROUP IX.—Rural:				
Bruce *	Pennsylvania Department of Agriculture.	1	1	++
Barnes Seedling	do	1	1	++
Carman No. 3	A. N. Newman, Phelps, N. Y.	2	2	++
Early Surprise *	Pennsylvania Department of Agriculture.	1	1	++
Fairbault Mammoth Prize	Farmers' Seed & Nursery Co., Faribault, Minn.	1	1	++
Golden Rule [9]	A. J. Derlith, Lincoln Park, N. Y.	2	2	++
Golden Rural	Joseph Harris, Coldwater, N. Y.	1	1	++
Golden Russet *	Pennsylvania Department of Agriculture.	1	1	++
Heath's Late Surprise *	do	1	1	++

[4] This is the local name for a stock that is in all respects Beauty of Hebron. It is not the Aroostook Prize belonging to section 2 of Group VIII, which is practically identical with American Giant and Jersey Giant; nor is it referable to Aroostook Pride, which is a true Green Mountain type.

[5] In the previous report (Lyman, G. R., and others. Op. cit.) this variety was referred to the Hebron group and is therefore so retained, but it is likely that Country Gentleman more properly belongs in section 2 of the Green Mountain group.

[6] Infected tubers somewhat off type and probably American Giant.

[7] American Giant is a type of the colored-sprout section of the Green Mountain group. Belonging to this same section are Jersey Giant and Aroostook Prize, identical with the first named, Idaho Rural, Charles Downing, and probably Cordner.

[8] This variety is now considered to be Burbank, which often occurs as a mixture with American Giant. Schaffnit (Versuche zur Bekämpfung des Kartoffelkrebses im Jahr 1918–19. *In* Ztschr. Pflanzenkrank., Bd. 30, p. 59–67. 1920) reports "Amerikanische Riesen" as immune.

[9] Rural type with heavy vines and late-growing habit.

TABLE 1.—*Reaction of American and European potato varieties to potato wart*—Contd.

Group and variety.	Source of seed.	Years tested.	Tests made.	Wart reaction.
1	2	3	4	5
GROUP IX.—Rural—Continued.				
Heavyweights	T. C. Gibbs, Fillmore, N. Y.	2	2	++
John Doolin [10]	Lawrence Bros., Byron, N. Y.	1	1	++
Kasoag Russet (same as Russet Rural).		1	1	++
Knowle's Big Cropper *	Pennsylvania Department of Agriculture.	1	1	++
Late Petoskey	....do.	1	1	++
Mason	Pennsylvania Agricultural Experiment Station.	1	1	++
Million Dollar *	Pennsylvania Department of Agriculture.	1	1	++
Nixon	Pennsylvania Agricultural Experiment Station.	1	1	++
Nonblight	Ford's Seed Co., Ravenna, Ohio	1	1	++
Pan-American (not certainly referable to this group).	Jos. Harris Co., Coldwater, N. Y.	1	1	+
Pearl of Canaan Valley	Farmers' Seed & Nursery Co., Faribault, Minn.	1	1	++
Prince Henry	Fred G. Smith, Scottsville, N. Y.	1	1	++
Rural New Yorker No. 2	J. F. Milliman, Naples, N. Y., and others.	4	>	++
Russet Rural	E. F. Dibble, Honeoye Falls, N. Y., and others.	4	>	++
Sensation	Woodruff Boyce Seed Co., Seattle, Wash.	1	1	++
Sir Walter Raleigh	Harold Hubbs, Kirkville, N. Y.	2	>	++
Tramp	Pennsylvania Agricultural Experiment Station.	1	1	++
GROUP X.—Pearl:				
Blue Victor	West Virginia Agricultural Experiment Station.	1	1	+
Dearborn [11]	Vaughan's Seed Store, New York City.	1	1	+
Pearl	Colorado Seed Co., Denver, Colo.	1	1	+
People's	William Wagner, Jerome, Idaho	1	1	+
Snowflake [12]	Farmers' Seed & Nursery Co., Faribault, Minn.	1	1	+
GROUP XI.—Peachblow:				
McCormick	Miss Hattie Girder, Bowling Green, Ky.	2	3	0
Do	J. Bolgiano, Baltimore, Md.	1	1	0
Red McClure	Colorado Seed Co., Denver, Colo.	1	1	0
Round Pinkeye	H. J. Presley, Port Huron, Mich.	3	3	0
White McCormick	Richard Wellington, College Park, Md.	1	1	0
Do	J. Bolgiano, Baltimore, Md.	1	1	0
GROUP XII.—Up-to-Date:				
American Wonder	California Seed Co., San Francisco, Calif.	1	1	++
British Queen	....do.	1	1	++
Cumming's Pride	P. A. Murphy, Charlottetown, Prince Edward Island.	1	1	++
Davies Warrior *	Pennsylvania Department of Agriculture.	1	.....	++
Dooley	H. J. Presley, Perry, Ohio	1	1	++
Producer	Portland Seed Co., Portland, Oreg.	1	1	++
Scotch Rural	Louis Rase, Frostburg, Md.	2	3	++
Up-to-Date	E. F. Dibble, Honeoye Falls, N. Y.	2	2	++
Wellington	Roy Harrington, Patten, Me.	2	2	++
Whitcomb *	Pennsylvania Department of Agriculture.	1	1	++
AMERICAN VARIETIES (unclassed):				
Black Christy	R. Lincoln, Knox, Pa.	2	2	±
Dakota Red [13]	Field Laboratory, Prince Edward Island.	2	2	0
Deposit Wonder	Deposit Seed Co., Deposit, N. Y.	1	1	+
Garnet Chili	Field Laboratory, Prince Edward Island.	2	3	+
Jersey Redskin	Henry F. Michel, Philadelphia, Pa.	1	1	+
Keeper	B. A. Corbett, Colebrook, N. H.	3	3	0
McIntyre [14]	Nova Scotia	3	5	++

[10] A potato identical with this is known under the name Dooley also; the variety Dooley used in these trials is an Up-to-Date type.

[11] The original Dearborn was a Rural type. The present variety undoubtedly belongs to the Pearl group.

[12] The original Snowflake is probably not now in existence; the variety under consideration is a renamed Pearl.

[13] This variety is widely and successfully grown as an immune potato in Newfoundland.

[14] A light and a dark strain of this variety exist, but the types are not wholly fixed.

TABLE 1.—*Reaction of American and European potato varieties to potato wart*—Contd.

Group and variety.	Source of seed.	Years tested.	Tests made.	Wart reaction.
1	2	3	4	5
AMERICAN VARIETIES (unclassed)—Continued.				
McIntyre	Field Laboratory, Prince Edward Island.	1	1	++
Mills Pride	do	1	1	?0
Unknown X	Highland, Pa. (local)	1	1	++
Unknown 114	W. G. Utterback, Sigourney, Iowa	1	1	+
FOREIGN VARIETIES (miscellaneous):				
Australian Blue	Agricultural Experiment Station, Sitka, Alaska.	2	3	++
B 2	Stat. Path. Veg., France	1	1	+
Bravo	H. M. Quanjer, Groeningen, Holland	1	1	+
Busola	H. Dolkowski & Sons, Galicia, Austria	1	1	++
Cacha Negra [15]		2	2	0
Casaker Salathornschen	Germany	1	1	0
Clifden Seedling	Field Laboratory, Prince Edward Island.	2	2	0
Clio	Poland	1	1	++
Commandant	Joha. Westerdijk, Holland	1	1	+
Concordia	E. Schaffnit, Germany	1	1	+
Czarine	Stat. Path. Veg., France	1	1	?0
Dalmeny	E. H. Grubb, Carbondale, Colo	1	1	+
Eldorado		1	1	+
Ekishirazu	Donald Reddick, Ithaca, N. Y	1	1	++
Eigenheimer	H. M. Quanjer, Groeningen, Holland	1	1	?0
Groningen Kron	do	2	2	++
Hamakua	E. S. Schultz, Presque Isle, Me	1	1	+
Institut de Beauvais	Stat. Path. Veg., France	1	1	++
Jaune Ronde	do	1	1	+
Kuckuck	E. Schaffnit, Germany	1	1	±
Martin's Horn		1	1	+
Northern Invincible	Field Laboratory, Prince Edward Island.	1	1	+
Pepo	E. Schaffnit, Germany	1	1	?0
Portuguese Purple		1	1	+
Quarantaine de la Halle	Stat. Path. Veg., France	1	1	?0
Rheingold	E. Schaffnit, Germany	1	1	?0
Roode Star [16]	H. M. Quanjer, Groeningen, Holland	1	1	?0
Russian Blue		1	1	+
Saxony	W. W. Rawson & Co., Boston, Mass	1	1	++
Saucisse	Stat. Path Veg., France	1	1	++
Success	Joha. Westerdijk, Holland	1	1	?0
Summit	Field Laboratory, Prince Edward Island.	1	1	+
Thieler	E. Schaffnit, Germany	2	2	±
Ursus	H. Dolkowski & Sons, Galicia, Austria	2	2	±
Do	E. Schaffnit, Germany	2	2	±
Violette d'Auvergne	Stat. Pat. Veg., France	1	1	++
Vitality	Alford, Lincolnshire, England	1	1	+
W. Richter	Joha. Westerdijk, Holland	2	2	±
Zbyszek	H. Dolkowski & Sons, Galicia, Austria	1	1	++
73	Stat. Path. Veg., France	1	1	++
ENGLISH AND SCOTCH VARIETIES:				
Abundance	Board of Agriculture and Fisheries, London, England.	2	2	0
Ally	do	3	3	0
America	do	1	1	0
Arran Chief	Field Laboratory, Prince Edward Island.	1	1	+
Arran Comrade	Board of Agriculture and Fisheries, London, England.	3	3	0
Arran Rose	do	3	3	0
Arran Victory	do	1	1	0
Ash Leaf		1	1	0
Berrick		1	1	++
Bishop	Board of Agriculture and Fisheries, London, England.	1	1	0
Burnhouse Beauty	do	1	1	0
Dargill Early	do	2	2	0
Duchess	do	2	2	0
Edzell Blue	do	3	3	0
Epicure		2	2	+
Golden Wonder	Board of Agriculture and Fisheries, London, England.	3	3	0
Great Scot	do	3	3	0

[15] A primitive type of *Solanum tuberosum* from Chile.
[16] Reported to be resistant but not immune in Germany.

TABLE 1.—*Reaction of American and European potato varieties to potato wart*—Contd.

Group and variety.	Source of seed.	Years tested.	Tests made.	Wart reaction.
1	2	3	4	5
ENGLISH AND SCOTCH VARIETIES—Continued.				
Irish Chieftain	Field Laboratory, Prince Edward Island.	2	2	0
Irish Queen	Board of Agriculture and Fisheries, London, England.	3	3	0
Kerr's New Pink [17]		2	2	0
Kerr's Pink	Board of Agriculture and Fisheries, London, England.	3	3	0
King George	do	3	3	0
Langworthy	do	1	1	0
Leinster Wonder	Field Laboratory, Prince Edward Island.	1	1	0
Lochar	Board of Agriculture and Fisheries, London, England.	2	2	0
Majestic	do	2	2	0
Mauve Queen	do	1	1	0
May Queen	do	2	2	0
Midlothian Early	do	2	2	+
Nithsdale	do	2	2	0
Provost	do	2	2	0
Rector	do	2	2	0
Resistant Snowdrop	do	1	1	0
Rhoderick Dhu	do	1	1	0
St. Malo Kidney	do	2	2	0
Scottish Triumph	Field Laboratory, Prince Edward Island.	1	1	?0
Shamrock	Board of Agriculture and Fisheries, London, England.	3	3	0
Sharpe's Express		1	1	+
Snowdrop	Board of Agriculture and Fisheries, London, England.	1	1	0
Templar	do	2	2	0
Tinwald Perfection	do	2	5	0
White City	do	3	3	0
Witch Hill	do	3	3	0

[17] One warted hill was found of this variety in 1920; it was saved separately from the uninfected hills, and both were planted in 1921. The progeny of the warted hill showed 40 per cent infection; the progeny of the wart free hills were not infected: the former are therefore believed to have been rogues. In plats of this variety grown by the State Department of Agriculture of Pennsylvania no infection has ever been observed.

In addition to the varieties included in Table 1, tests have been made of an extensive collection of seedlings bred by William Stuart, of the Bureau of Plant Industry. Two principal ends have been sought in these seedling trials: (1) The immediate attainment of new types of immune potatoes which might show superior adaptation to the climate and soil of the wart-infested areas and hence might be introduced into general culture and (2) the development of information upon the inheritance of susceptibility and immunity in the progeny of crosses which combine in various ways immune and susceptible parents. Two preliminary reports upon the results of these studies have appeared.[10]

To date, 194 seedlings, practically all of known parentage, have been grown on the wart plats at Freeland, Pa. Of these seedlings 12 appear to be certainly immune and 48 have resisted or escaped infection in a single test. Of the 12 immunes, 7 have been under observation for four years and 5 have been tested for three years. In stability of the immune character and in commercial value, these seedlings are comparable with the named varieties; and further tests may demonstrate that superior-yielding immune types are already at

[10] Lyman, G. R., and others. Op. cit.
Orton, C. R., and Weiss, Freeman. The reaction of first-generation hybrid potatoes to the wart disease. *In* Phytopathology, vol. 11, pp. 306–310. 1921.

hand and may be introduced into general culture. In particular, a potato is desired which shall combine immunity with the drought and heat resisting qualities and other desirable characters of the Rural New Yorker. As the details of this study are of technical interest only and as a report has been issued which embodies the results attained to date [11] reference to the seedling tests is here limited to the statement that immune seedlings having as one parent a Rural type are already at hand, but the testing of their commercial value as compared with standard varieties will be the work of several years. Meantime, new hybrids of similar origin will be sought, and all wart-immune seedlings will be subjected to careful tests of yielding capacity, general adaptability, and disease resistance, to the end that should any of them be brought into general culture their introduction will be a distinct gain over existing varieties.

TESTS WITH MISCELLANEOUS SOLANACEOUS SPECIES.

One of the favored theories to account for the origin of the wart, or at least its sudden appearance and rise to economic importance in Europe, has been that the pathogen has spread to the potato from some other host, which is believed to have been some native plant upon which it produced only inconspicuous malformations and hence was overlooked. In support of this hypothesis it has been shown that this disease appeared rather suddenly in England during the last decade of the nineteenth century. Although some earlier accounts antedating this by 20 years may have actually referred to the same malady, nearly 150 years elapsed after the introduction of the potato into general culture in Europe before any mention of this disease is found. Its slow extension during the next 10 or 15 years may have been due to the gradual adaptation of the parasite to a new host, upon which it ultimately came to have its present marked pathological effect, leading to its recognition. The rapid spread in the British Isles within recent years can be accounted for, as Taylor [12] has shown, by the introduction into general cultivation of susceptible potatoes, together with the movement of seed stock, particularly from Scotland after the disease had become well established there. It seems unlikely that the wart pathogen was introduced into Europe along with the original potato, since some of the endemic species of Solanum of South America most closely related to *Solanum tuberosum* resist infection [12] (see note 15, Table 1), although if such immunity could have developed through long association with the pathogen this evidence is not significant. The comparatively recent appearance of this striking malady is better evidence against such early introduction. On the other hand, Cotton [13] has found that the common garden weeds, *Solanum nigrum* L. and *S. dulcamara* L., are susceptible to infection by *Synchytrium endobioticum* (Schilb.) Perc., although they have never been found warted in nature.

Although the biological validity of the theory which assumes that this parasite within recent times has passed over to a more congenial host may be open to serious objections, the importance from the

[11] Orton, C. R., and Weiss, Freeman. Op. cit.
[12] Taylor, H. V. The distribution of wart disease. *In* Jour. Min. Agr. (Gt. Brit.), vol. 27, pp. 733-738, 863-867, 946-953. 1920-21.
[13] Cotton, A. D. Host plants of Synchytrium endobioticum. *In* Roy. Gard. Kew, Bul. Misc. Inform., 1916, pp. 272-275. 1916.

standpoint of quarantine administration of determining the host range in America requires the testing of all obtainable botanical relatives of the potato. Such tests have been carried on during four years both in the open at Freeland, Pa., and in the greenhouse at Washington, D. C. The possibility of the wart pathogen attacking nonsolanaceous plants which occur in infested gardens, either native or cultivated, has been investigated, as previously reported[14] and also by the present writers, but no indication has been found that such extension of host range takes place. The species listed in Tables 2 and 3 have not been infected by wart when grown in infested soil. In both the greenhouse and garden tests susceptible potatoes were grown under similar conditions as controls, and in all cases these developed wart infections.

The solanaceous species listed in Table 2 have been grown in wart-infested soil in the greenhouse at Washington, D. C., under favorable conditions for wart infection, as shown by the results with controls. Infection of these species failed. On the other hand, infection of the black nightshade (*Solanum nigrum* L.) and bittersweet (*S. dulcamara* L.) has followed experimental inoculation.

TABLE 2.—*Solanaceous species of plants tested for susceptibility to potato wart in pots in the greenhouse at Washington, D. C.*[1]

[Infection of all these species failed.]

Number and name of species.	Number of plants.	Number and name of species.	Number of plants.
No. 1. Solanum atropurpureum Schrank	5	No. 8. Datura humilis flava	3
No. 2. Solanum gilo Radii	4	No. 9. Datura metel L	1
No. 3. Solanum lobelii Lenore (=integrifolium Poir.)	4	No. 10. Datura stramonium L	2
		No. 11. Datura tatula L	2
No. 4. Solanum pseudocapsicum L	5	No. 12. Cyphomandra betacea Sendt	3
No. 5. Nierembergia gracilis Hook	5	No. 13. Physalis sp	10
No. 6. Datura atroviolacea Hill	1	No. 14. Solanum aculeatissimum Jacq	4
No. 7. Datura bertolonii Parl. ex Guss. (D. ferox L.)	1	No. 15. Solanum marginatum L	6

[1] The writers are indebted to J. B. Hill, of Pennsylvania State College, for furnishing seed of all species tested except Nos. 4, 10, 11, and 12.

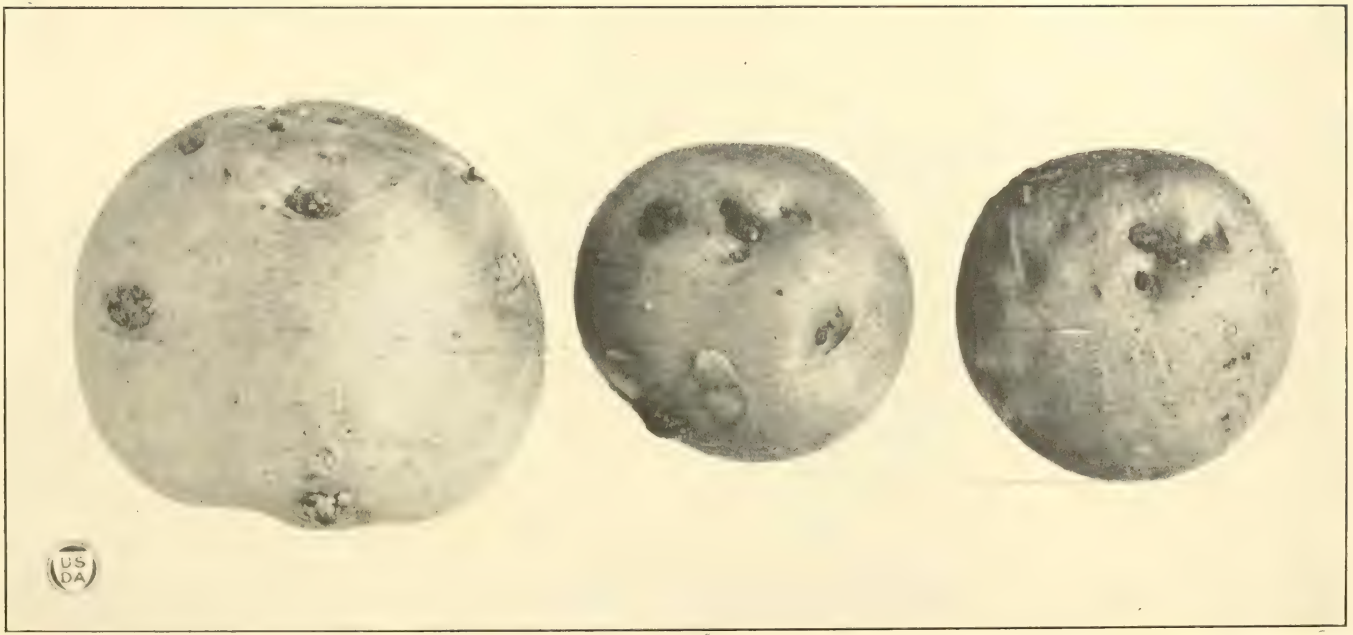
The solanaceous species listed in Table 3 have been grown in wart-infested gardens at Freeland and Upper Lehigh, Pa., under very favorable conditions for the infection of susceptible potato varieties. Certain of these species have been tested for two years in different plats, but wart infection has not occurred.

To the knowledge of the writers *Solanum nigrum* has not been found as a weed in any wart-infested garden, either in Pennsylvania or West Virginia, nor has it been observed in the quarantined area in eastern Pennsylvania. Similarly, *Solanum dulcamara* has been collected only occasionally within this district, growing cultivated in noninfested gardens. None of the solanaceous annuals, such as *Solanum integrifolium*, *Datura tatula*, and others, which have been grown possess underground parts which ordinarily would prove susceptible to infection by a parasite of the nature of Synchytrium. The stem is usually single below ground, without lateral shoots or buds, and the firm epidermis and tough cortex of the crown and taproot would

[14] Lyman, G. R., and others. Op. cit.

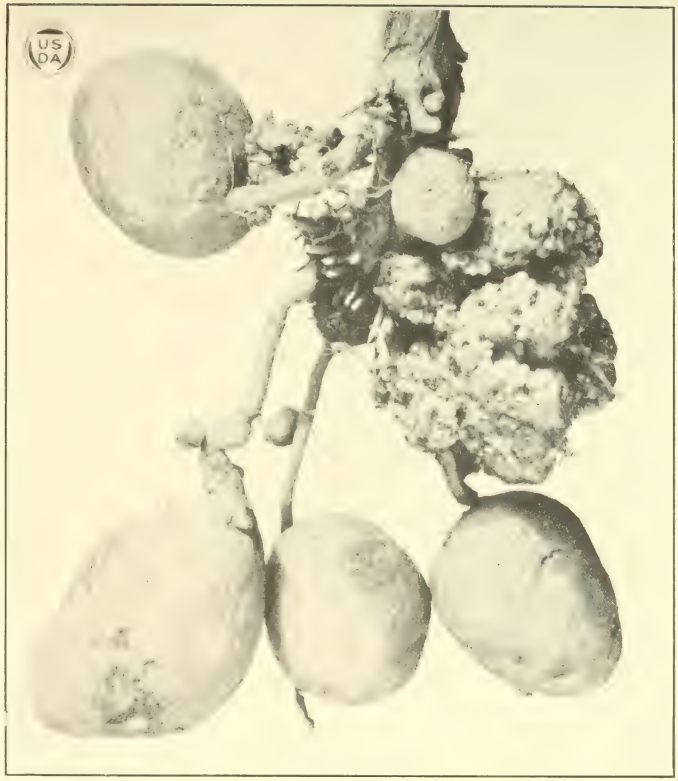
POTATO VARIETIES OF THE EARLY MICHIGAN GROUP.

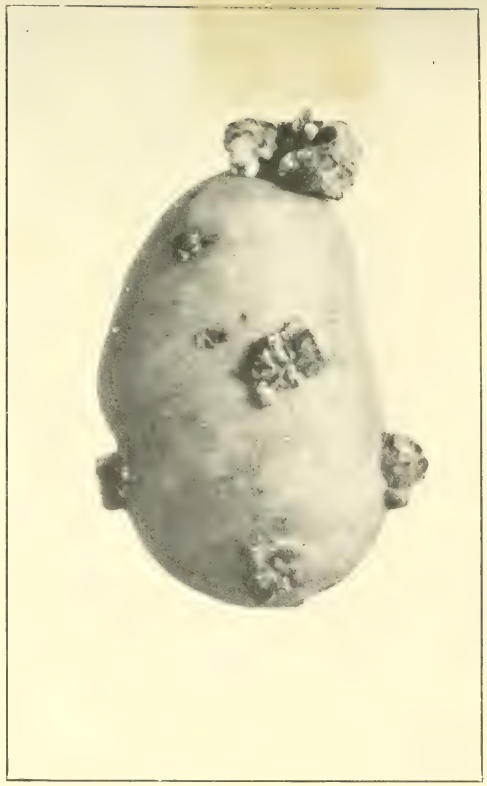
The three varieties illustrate the diversity in disease reaction within a horticultural group. From left to right: Ehnola, immune; Early Sunrise, very susceptible; Extra Early Sunlight, immune.



BLISS TRIUMPH POTATO TUBERS.

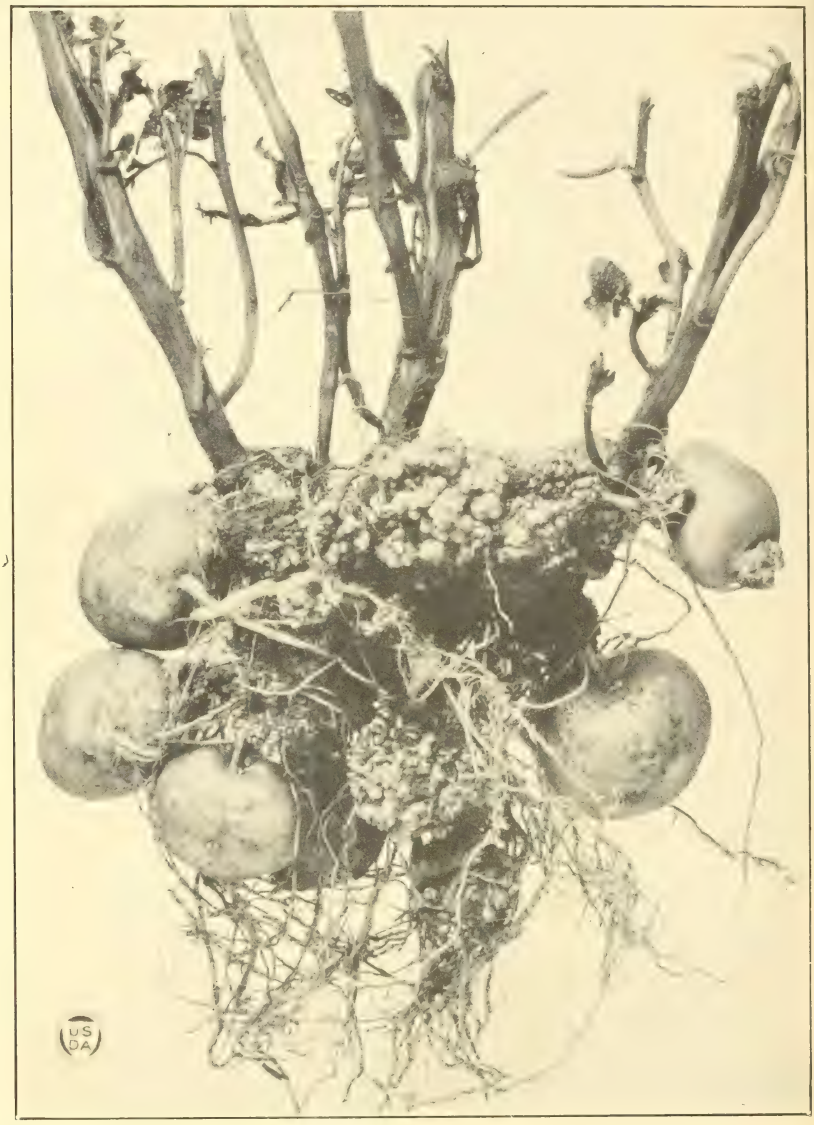
The slight tuber infection shown on this variety is an example of partial resistance in a plant part. Compare with the left-hand figures of Plate III, showing stolon infection in the same variety.





POTATO VARIETIES MODERATELY SUSCEPTIBLE TO WART.

Blue Triumph (at left), showing stolon infection, but tubers almost free from the disease; at right, Noland Gem.



ROOTS AND TUBERS OF UP-TO-DATE POTATO.

A variety very susceptible to wart.

seem to be an unfavorable tissue for the entry of zoospores or to show a marked growth response resulting from infection. In the tomato and eggplant, adventitious shoots arise from the underground portion of the stem, usually late in the season. Infection of these buds or of the shoots occurs in the tomato, but fails through the operation of an unknown factor in the eggplant.

TABLE 3.—*Solanaceous species of plants tested for susceptibility to potato wart in gardens at Freeland and Upper Lehigh, Pa., in 1920 and 1921.*

[Infection of all these species and varieties failed.]

Species.	Number of plants.		Species.	Number of plants.	
	1920	1921		1920	1921
Solanum melongena L. var. esculentum Ness. (eggplant):			Datura stramonium L. (stramonium)	.....	20
Chinese White	.....	7	Datura tatula L. (purple tatula)	.....	20
Black Beauty	.....	30	Solanum integrifolium Poir. (=S. lobelii Lenore)	.....	9
New York Improved	.....	13	Nicotiana rustica L. (wild tobacco)[1]	12	4
Capsicum annuum L. (peppers):			Nicotiana tabacum L.:		
Ruby King	6	.....	Pennsylvania Seedleaf	6	23
Long Red Cayenne	.....	15	Connecticut Havana	9	.....
Shell's New Quality	6	.....	White Burley	10	.....
Hot Pepper	6	.....	Pennsylvania Broadleaf	5	.....
World Beater	6	.....	Mammoth	3	.....
Pimento	.....	20	Nicandra physalodes (L.) Pers. (apple of Peru)[1]	(2)	(2)
Physalis pubescens L. (Burpee husk tomato)	.....	14	Petunia violacea Lindl. (petunia)	18	12
Solanum carolinense L. (horsenettle)	.....	12	Nicotiana paniculata L.	6	.....
Solanum dulcamara L. (bittersweet)	8	.....			

[1] These species occur as weeds in one of the gardens most heavily infested with wart.
[2] Numerous.

While the testing of potential hosts will be continued, particularly with the aim of including all temperate-climate species of Solanum, it is believed that the failure to find new hosts among the several cultivated and most common indigenous solanaceous plants of this region (with the exceptions mentioned) makes it improbable that the pathogen is able to maintain itself in this region on unsuspected hosts, which therefore require particular quarantine action.

VARIETAL TESTS WITH TOMATOES.

The susceptibility of the tomato to infection by *Synchytrium endobioticum* (Schilb.) Perc. was shown by Kunkel and Orton in 1919.[15] Tests with tomatoes have been carried on each year since then, but not all factors entering into the tests have been amenable to satisfactory control so it is not yet considered that complete and entirely reliable data as to the susceptibility of tomato varieties are at hand. The present state of information in this respect is shown in Table 4, in which are listed only the varieties that have been proved to be susceptible.

The tomato is much less readily susceptible to wart infection than the potato, and the development of the overgrowths is always less marked. Infection usually occurs in buds or adventitious shoots on the main stalk below the soil surface. It therefore appears

[15] Lyman, G. R., and others. Op. cit.

ordinarily late in the season, usually not until September, but by setting out tomato seedlings in a wart-infested garden in August infection has been brought about on very young plants. Similarly infection has been produced on young plants grown in water cultures. The readiness with which infection may occur is influenced to a considerable extent by hilling up the soil about the plants, thus inducing growth activity in the buds of the covered part of the stem. Under these conditions tumors which are evidently malformed stems or leaves and sometimes reach 2 centimeters in diameter are produced. Kunkel and Orton[16] reported root infections also, a noteworthy case, since potato roots apparently never become infected. While an examination of Kunkel's preparations shows indubitable resting spores of the wart pathogen in a considerably disorganized tissue, which is nevertheless of root topography, subsequent observations have not brought to light wart infections on tomato roots. In 1920 many of the tomatoes under test developed very striking lesions in the nature of fusiform swellings or pulvinate outgrowths of the cortex of the larger feeding roots at the base of the stalk. The smaller "brace roots" springing from near the crown were not observed to be so infected. These lesions were at first regarded as being due to Synchytrium, but a microscopic examination of them in the fresh state consistently failed to show recognizable stages in the life cycle of this pathogen. Fixed and embedded material disclosed the presence of extensive areas of infected host cells, resembling the figures given by Melhus[17] for infection of tomato and potato roots by powdery scab (*Spongospora subterranea* (Wallr.) Johnson). Veritable "krankheitsherde" were commonly present, involving from a few to several hundred host cells in which each host nucleus was surrounded by a plasmodium or an aggregation of amœbæ containing numerous minute nuclei. The host nucleus was greatly enlarged, but appeared otherwise normal. The parasitic nuclei agreed in size with the figures of Melhus representing Spongospora; they possessed a definite nuclear membrane, a central nucleolus, and usually a few delicate chromatin strands. No division stages have as yet been made out in these nuclei, but there was clear evidence of giant host cells showing mitotic nuclear division which was not immediately followed by cell division. Neither have any stages suggesting spore ball formation in Spongospora as described by Osborn[18] been observed. A complete cytological investigation of these galls is in progress; meantime, they are provisionally referred to *Spongospora subterranea*. It is noteworthy, however, that powdery scab affecting potatoes had not been reported from any part of Pennsylvania up to this time, but a careful search for its presence, made subsequent to finding these tomato-root infections, disclosed its limited occurrence on certain English varieties growing in a different garden.[19]

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[16] Lyman, G. R., and others. Op. cit.

[17] Melhus, I. E., Rosenbaum, J., and Schultz, E. S. *Spongospora subterranea* and *Phoma tuberosa* on the Irish potato. *In* Jour. Agr. Research, v. 7, pp. 213–254, 1 fig., pl. A (col.), 7–14. Literature cited, p. 253. 1916.

[18] Osborn, T. G. B. Spongospora subterranea (Wallroth) Johnson. *In* Ann. Bot., vol. 25, pp. 327–341, pl. 27. Bibliography, p. 340. 1911.

[19] Shapovalov, Michael. "Skin spot," a stage of powdery scab. (Abstract.) *In* Phytopathology, vol. 12, pp. 37–38. 1922.

TABLE 4.—*Varieties of tomatoes found to be susceptible by planting in infested soil in the field.*

[EXPLANATION.—The plus mark (+) indicates susceptibility; a blank (—) indicates no test.]

Variety.	1919	Number of plants.						Variety.	1919	Number of plants.					
		1920		1921		1922				1920		1921		1922	
		Grown.	Infected.	Grown.	Infected.	Grown.	Infected.			Grown.	Infected.	Grown.	Infected.	Grown.	Infected.
Burbank	+	—	—	—	—	—	—	Matchless	—	4	2	—	—	—	—
Carter's Sunrise	+	6	6	—	—	—	—	Michigan Early	—	6	1	—	—	—	—
Early Detroit	+	4	4	—	—	15	2	Ponderosa	—	6	2	—	—	—	—
Landreth's Red Rock	+	—	—	—	—	—	—	Redhead	—	6	4	—	—	—	—
Magnus	+	5	1	—	—	—	—	San Jose Canner	—	3	3	—	—	—	—
Maule's New Imperial	+	—	—	—	—	—	—	Stone	—	6	6	—	—	6	0
Success	+	—	—	—	—	7	0	Trucker's Favorite	—	5	4	—	—	—	—
Beauty	—	4	4	—	—	17	0	Crackerjack	—	—	—	4	2	—	—
Dwarf Champion	—	6	1	—	—	—	—	Comet	—	—	—	—	—	18	[1] 1
Duke of York	—	6	5	—	—	—	—	Trophy	—	—	—	—	—	6	3
Earliana	—	12	4	—	—	14	2	Acme	—	—	—	—	—	10	1
John Baer	—	4	4	4	1	13	2	Lorillard	—	—	—	—	—	7	2
Globe	—	6	2	—	—	—	—	Bonny Best	—	—	—	—	—	5	1
								Red Cherry	—	—	—	—	—	4	1
								Yellow Cherry	—	—	—	—	—	3	1

[1] Test with seedlings only.

In 1921 about 85 varieties of tomatoes were grown, but owing to the early maturity of the vines brought about by hot weather and Septoria leaf-spot and also owing to very light infestation of the soil, only a few plants developed wart infection. In 1922 certain varieties, including some not hitherto tested, were grown in well-infested soil or were subjected to experimental inoculation. The observation that tomatoes may become infected at an early stage of growth was confirmed, and additional evidence was obtained that plants nearing maturity are in general more susceptible. It appears from the results of field tests during four years that the precise conditions requisite for the infection of tomatoes can be elucidated only by experimental inoculation in the greenhouse with all factors subject to control. All the trials with tomatoes to date have not given a definite answer to the question whether immune varieties comparable to immune potatoes really exist. This is a point of much scientific interest.

The statement may be ventured, however, that the tomato has not been found to possess such significance as a host plant in the Freeland area as to require special consideration in the potato-wart quarantine.

SUMMARY.

A number of American varieties of potatoes have been shown to be immune to wart caused by *Synchytrium endobioticum* (Schilb.) Perc. This conclusion is based upon tests extending from one to four years in which such varieties remained free from wart infection when grown in heavily infested soil in which susceptible varieties were generally and severely infected.

The varieties which have thus proved to be immune are: Early Eureka, Early Petoskey, First Early, Cordon's Early Snowflake, Flourball and Irish Cobbler, belonging to the Cobbler group; Early

Harvest, Ehnola, Extra Early Sunlight, and White Albino, of the Early Michigan group; Spaulding Rose, of the Rose group; Burbank, of the Burbank group; Bountiful, Delaware, Gold Coin, Green Mountain, Green Mountain Junior, Idaho Rural, McGregor, McKinley, and Norcross, of the Green Mountain group; McCormick, Round Pinkeye, and White McCormick, of the Peachblow group; and Dakota Red and Keeper, unclassified as to group.

Most of the varieties of tomatoes tested have proved to be susceptible to wart, but some of the tests have been inconclusive, and it is not yet certain whether different degrees of susceptibility and resistance exist in the tomato. In general, the tomato becomes infected less readily than the potato, requiring particularly favorable environmental conditions and appropriate stages of host development.

A number of solanaceous plants, including the native solanaceous weeds of Pennsylvania, and the eggplant, tobacco, petunia, and pepper, which are in common cultivation, have been tested for susceptibility to the wart pathogen, but infection has thus far failed.

II.—THE ADAPTABILITY AND USE OF WART-IMMUNE VARIETIES OF THE POTATO IN THE QUARANTINED AREAS OF PENNSYLVANIA.

By R. E. Hartman.

The results of experiments to determine the adaptability of the common commercial wart-immune varieties of potatoes, Green Mountain, Irish Cobbler, Spaulding Rose, and McCormick, have shown that these varieties are all well adapted to the present quarantined areas. This is perhaps accounted for by the fact that the quarantined areas of Pennsylvania are all at altitudes ranging from 1,200

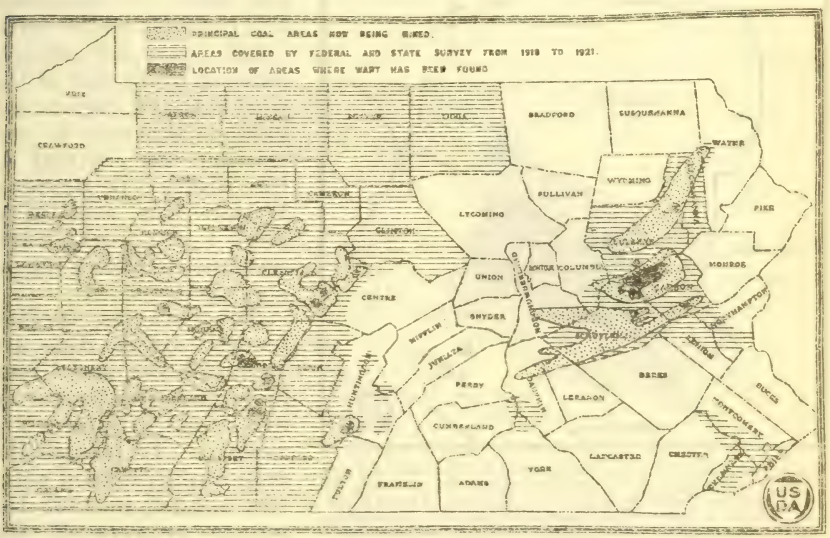

Fig. 2.—Outline map of Pennsylvania, showing the distribution of potato wart as determined by surveys completed in 1921. All infested areas are in coal-mining localities and are generally at high altitudes.

to 2,000 feet, where the climatic conditions of temperature and rainfall are favorable for potato production. (Fig. 2.)

The use of wart-immune varieties of potatoes was adopted as a quarantine policy in 1920. As a preliminary step in this direction all owners of gardens and fields actually infested with potato wart were permitted to grow only wart-immune varieties. The particular variety selected for this purpose was Spaulding Rose, which is a potato of good commercial quality and in addition possesses such outstanding varietal characteristics that the detection of mixtures is comparatively easy during the whole season of summer inspection. During the first season approximately 800 bushels of Spaulding Rose potatoes were used with very pronounced success in 300 fields and gardens, and in 1921 it was decided to extend the use of this immune variety to all the areas under quarantine.

The production of this wart-immune seed is very carefully regulated by the Pennsylvania Department of Agriculture in order to be certain that each variety is free from mixtures. For the season of 1921 approximately 10,000 bushels of Spaulding Rose potatoes were grown in Potter County, Pa., and distributed to growers in the quarantined areas through the ordinary commercial channels. The results of the first season of the general use of immune varieties have proved very successful, as the newly introduced immune varieties are far superior to the varieties formerly grown in general appearance, stand, and yield.

As a further means of preventing the spread of potato wart, it was decided in 1921 to establish a safety zone, surrounding the quarantined area. (Fig. 3.) This area is largely agricultural, comprising 2,000 farms and a few scattered rural villages, and since it comprises and includes all the cultivated land for several miles on every side of the wart-infested region the value of this zone in preventing the spread of the disease is obvious. Within this area after April 1, 1922, only wart-immune varieties could be grown.

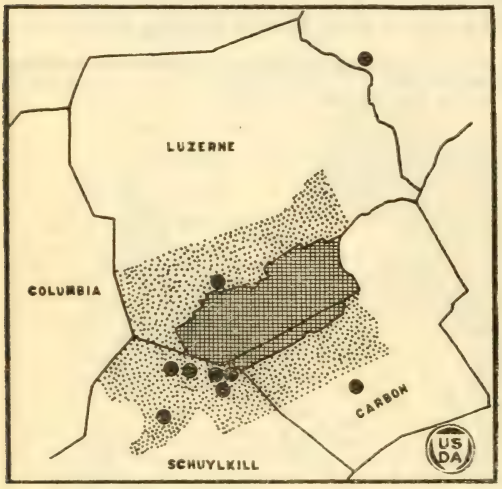

FIG. 3.—Outline map of Luzerne and Carbon Counties and portions of Columbia and Schuylkill Counties, Pa., showing the area heavily infested by potato wart (marked by cross hatching) which is under rigid quarantine and the surrounding safety zone (marked by small dots) in which a limited quarantine is maintained.

The varieties selected for the safety zone are Irish Cobbler and Green Mountain, the former an early and the latter a late variety. To furnish the large supply of seed potatoes needed in 1922 the potato growers of the safety zone organized potato associations and brought in and grew during the season of 1921 under State inspection and supervision 50,000 bushels of Green Mountain and Irish Cobbler potatoes. To obtain experimental data as to the adaptability of these varieties to the safety zone, these potatoes were grown on 42 different farms in the three portions of the counties comprising the safety zone, where they produced an average yield of 360 bushels per acre, as compared with an average of 225 bushels per acre for local varieties.

The experience gained in connection with the supervision of the seed production of wart-immune varieties for the quarantined area has emphasized the absolute necessity of careful inspection and regulation. The loose application of a multitude of names to various strains of our commercial varieties has resulted in such uncertainty in regard to the identity of any individual stock that it has been found necessary to test every prospective seed stock for wart im-

munity and then carefully supervise the propagation of seed from it before it can be certified for use in quarantined areas.

The results of the adaptability tests of the selected wart-immune varieties would seem to indicate that these can be profitably used in the quarantined areas of Pennsylvania. However, should the use of wart-immune varieties become necessary in other sections of the State where less favorable temperature and moisture conditions obtain, it will be necessary to provide wart-immune varieties better adapted to such conditions. Since the possibility of the spread of the wart into other sections of the State is a threatening factor, continued efforts should be made to develop immune varieties of such diverse types that one or more of these varieties will be available for the commercial or home potato grower in every part of the State.

III.—THE STABILITY OF WART IMMUNITY.

By Freeman Weiss.

Since the use of immune varieties continues to be the most effective means known of dealing with potato wart, both as to avoiding the loss of the potato crop in infested districts and as to restricting the extension of the pathogen beyond its present range, the question of the permanence of immunity is of great concern to growers and quarantine officials alike. Fortunately, the information which has been adduced in England and in Germany from immunity tests, which have extended over a much longer period than the similar line of investigation in the United States, furnishes a satisfactory answer to this question. In Leaflet 105,[20] issued in 1918 by the British Board of Agriculture and Fisheries, the following statement appears:

> The trials carried out at Ormskirk . . . demonstrate beyond all doubt the absolute immunity . . . of certain varieties. Disappointment in the past as to resistant varieties has been due either (*a*) to wrongly named seed, or (*b*) to the presence of "rogues," or (*c*) to the use of varieties which, though formerly supposed to be immune, had not been properly tested on badly and uniformly infected soil. As far as known the immunity of no variety which has been thoroughly tested has as yet broken down.

Subsequent evidence has not yet appeared from the English tests which in any way requires the modification of this conclusion, and the experience of three years with immune varieties in the United States is wholly confirmatory. It is significant that the list of immune varieties which was published[21] as a result of the first year's trials has not required amendment except to add new varieties.

Schaffnit,[22] however, holds that immunity is not absolute, but only relative; that varieties showing immunity under normal conditions may lose this faculty as soon as the plant no longer exhibits its normal form of development or is weakened as a result of tuber-transmissible pathological conditions expressed in leaf-roll and mosaic mottling. The opinion has been expressed by Gough,[23] however, that the loss of immunity reported by Schaffnit is probably the result of using originally impure seed stocks or the occurrence of mixtures during the test.

Some data in this connection have been derived from the tests at Freeland, Pa. The immune varieties which were imported from England in 1919 exhibited in their first year a considerable proportion of leaf-roll and mosaic mottling. The seed for 1920 was saved from these same stocks and increased percentages of leaf-roll and mosaic, in some cases affecting the entire crop, were noted in the 1920 plats. Both diseases appeared to a greater or less extent among

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[20] Anonymous. Wart disease (black scab) of potatoes (Synchytrium endobioticum Percival). Leaflet Bd. Agr. and Fish. [Gt. Brit.], No. 105, 6 p., 4 fig. (Issued 1904, rev. 1918).

[21] Lyman, G. R., and others. Op. cit.

[22] Schaffnit, E. Versuche zur Bekämpfung des Kartoffelkrebses in Jahr 1918–19. In Ztschr. Pflanzenkrank, Bd. 30, p. 59–67. 1920.

[23] Gough, G. C. [Discussion on immunity from wart disease.] *In* Rpt. Internat. Potato Conf., 1921, p. 103. [1922?]

the American variety and seedling collections also. Individual plants showing particularly marked symptoms were selected that year, and tubers were saved from these for planting a mosaic and leaf-roll pathologium in 1921. The immune stocks so selected were grown in the most heavily infested garden available, where susceptible sorts regularly showed total infection. The results of this experiment appear in Table 5.

In 1922 a further planting was made of stocks of certain English immune varieties imported in 1919, which had since become thoroughly degenerate and exhibited pronounced symptoms of crinkle, mosaic necrosis, streak, and leaf-drop, combined in some cases with extreme dwarfing.

It is noteworthy that not a single instance of deterioration of immunity was observed, although all plants and tubers were examined minutely, and susceptible sorts, interplanted, were generally infected.

TABLE 5.—*Tests of the stability of wart immunity in degenerate stocks of potato varieties at Freeland, Pa., in 1919, 1920, and 1921.*

Variety.	1919		1920		1921	
	Foliage.	Wart.	Foliage.	Wart.	Foliage.	Wart.
Abundance	Healthy	0	Leaf-roll	0	Leaf-roll and mosaic.	0
Bishop	do	0	do	0	do	0
Dargill Early	Mosaic	0	Mosaic	0	Mosaic	0
Edzell Blue	Healthy	0	Leaf-roll	0	Leaf-roll and Mosaic.	0
Majestic	do	0	do	0	do	0
May Queen			Mosaic	0	Mosaic	0
Early Petoskey	Healthy	0	Leaf-roll	0	Leaf-roll and mosaic.	0
Extra Early Sunlight	do	0	Curly dwarf	0	Curly dwarf	0
Green Mountain Junior	do	0	Mosaic	0	do	0
Irish Cobbler	do	0	Leaf-roll and mosaic.	0	Leaf-roll and mosaic.	0
Keeper	Curly dwarf	0	Curly dwarf	0	Curly dwarf	0
Round Pinkeye	Mosaic	0	Leaf-roll and mosaic.	0	Leaf-roll and mosaic.	0
Seedling No. 3615	do	0	Curly dwarf	0	do	0
Seedling No. 37662	do	0	Mosaic	0	Mosaic	0
Seedling No. 38899	do	0	do	0	do	0
Seedling No. 39304	Healthy	0	do	0	do	0
Richter [1]			Healthy	(2)	Mosaic and leaf-roll	(3)
Rural New Yorker					do	(4)

[1] This, a slightly susceptible variety, was introduced into the test to see if its tendency to resistance diminished in degenerating stocks.
[2] One warted tuber.
[3] One warted stolon.
[4] Wart 50 per cent.

During an experience covering three years in the culture of the immune varieties, Edzell Blue, Spaulding Rose, Irish Cobbler, and Green Mountain, in the quarantined area of eastern Pennsylvania, many cases of mosaic and leaf-roll infection have been observed, but in no case has immunity to wart been affected. Particularly during 1921 were the potatoes grown in this district subjected to very adverse conditions brought about by drought, warm weather, severe aphid and flea-beetle injury, and competition with weeds. Although plantings of susceptible potatoes continued to develop wart under even these conditions, no immune variety has yet broken down. Similarly, injuries to the tuber caused by common scab or by millipedes and burrowing insect larvæ have never been observed to predispose the affected part to wart infection, although such injuries must expose the cortical and meristematic tissues beneath the protective periderm.

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